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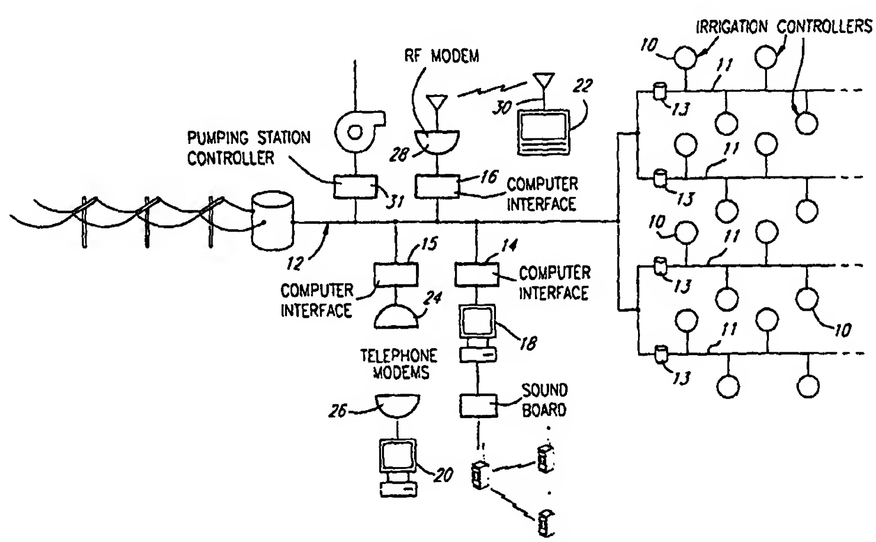

(57) Abstract

An irrigation system for controlling a plurality of watering stations whereby each station is irrigated in accordance with the specific soil needs at that station; the system includes a plurality of irrigation controllers (10), one at each watering station, each controller (10) including a power line (11) transceiver, a micro-processor, an erasable non-volatile memory, and an actuating circuitry for activating a valve actuator in response to data received from a computer (18), a power line network (11, 12) powers the controllers (10) and serves as a medium through which the controllers (10) communicate between one another and the computer (18).

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TITLE OF THE INVENTION

Control system for the irrigation of watering stations.

FIELD OF THE INVENTION

The present invention relates to a system for controlling a plurality of watering stations whereby each station is irrigated in accordance with the specific soil needs at that stations and, more particularly, to a computer in which feedback from water content and salinity sensors is provided.

BACKGROUND OF THE INVENTION

Systems for automatically irrigating and/or fertilizing golf courses and other sports turf, agricultural operations, contaminated soils, and the like are well known.

Conservation of ground water by more efficient irrigation and a reduction of the pollution of these waters due to fertilizing are a constant concern to preserve the environment.

In the past, it has been common to operate irrigation systems by timing devices to carry out methods which, in fact, did not take into account the actual needs of the soil for moisture. Such devices are controllers which take care of typically 12 to 24 watering stations, each station consisting of one or few sprinklers. A typical controller requires 120 volts supply (or 220 volts in some foreign countries) and supply 24 volts AC to the valve actuator of each watering station. For instance, more than 10 controllers are most often required to cover a complete golf course of 18 holes. Since the stations are far apart, a lot of low voltage cable between the controller and its sprinkler valves must be installed in the ground, which is expensive, both to install and maintain.

Some controllers can be controlled at a distance via an extra twisted pair of cables and a personal computer. The other controllers require the user to travel on the field in order to program each controller individually.

Because of the variable topography and geometry of the irrigated fields, all watering stations do not require the same amount of watering. Therefore, the user must set a different number of minutes of watering per day for each station according to its specific needs. The process of finding the exact number for each station is tedious and empirical. Most likely, the user will oversize this number of minutes in order to prevent water shortage. Unfortunately, this practice will result in water waste.

Some irrigation control systems use a meteorological station to get real-time evapo-transpiration (E.T.) rates and modulate irrigation time accordingly. This option is useful for adjusting watering with respect to changing meteorological conditions. However, the E.T. reading does not provide any individual watering station data, nor does it necessarily provide exact average data. Therefore, it does not relieve the user from conducting the station by station calibration described above.

Systems have been developed using various types of buried sensors to determine when the soil requires watering. Typical of such apparatus may be found described in U.S. patents 2,812,976 (Hasencamp), 2,611,643 (Higgins), 3,961,753 (Sears) and 4,197,866 (Mal). These systems utilize an in-ground sensor (or probe), a threshold device which will turn on the irrigation when below a certain indicated moisture level, and timers.

These moisture sensors are based on conductivity m asurement and therefor are greatly influenced by th salinity of the soil

as well as by the moisture. Therefore, the operation of such systems will be influenced by the operator's fertilizing schedule.

In the early 80's, Dr Clarke Topp, a physicist at Agriculture Canada, established a mathematical relationship between permittivity of a soil and its water content. This relationship has the advantage to be almost independent of soil granularity (clay vs silt vs sand) and presence of dissolved salts, including natural ones and artificially added fertilizers.

Permittivity is the ability of a material to be polarized by an electric field. By definition, the relative permittivity of the vacuum (or air) is 1,0. By comparison, the permittivity of most soils vary from 2,5 to 4,0. On the other hand, the permittivity of water, at room temperature, is 80. The soil water content varies almost linearly with the square root of the soil permittivity.

Dr Topp was also innovative in using a fairly typical device called TDR (Time Domain Reflectometry), developed for testing cables, to determine the permittivity of a soil. The TDR sends a pulse through a coaxial cable to a probe buried in the soil sample, and measures the time it takes to come back. The probe is made of two parallel rods and acts as a transmission line, where the soil is the dielectric. Measuring traveling time allows easy calculation of the signal velocity since the probe length is known, and the velocity is proportional to the speed of light divided by the square root of permittivity. Therefore, the traveling time is essentially linear with water content. The wetter a soil is, the slower will be the signal velocity.

The TDR also allows determination of soil conductivity by measuring the attenuation of the reflected signal. Soil conductivity measurement becomes useful whenever water content is known through

permittivity measurement or otherwise. It then allows to determine soil salinity. In turn, knowing soil salinity can lead to fertilizer measurements. Therefore, conductivity and permittivity together can serve for scheduling soil fertilization, fertigation or irrigation with reclaimed water.

Some manufacturers have developed sensors that work in the frequency domain (FDR) instead of the time domain (TDR). They measure the complex impedance of the probe at a given frequency. The imaginary part of impedance is related to permittivity whereas the real part to the conductivity. This approach lowers the cost of required electronic components dramatically but has not reached the precision of TDR so far.

One system found described in U.S. patent No. 5,545,396 issued October 8, 1985 to Miller et al. describes a multiplicity of moisture and salinity sensors buried within the route zone of crops and includes means for measuring the complex impedance of the sensor in which the reactive part is a measure of the moisture content of the soil and the resistive part is a measure of the salinity of the soil. The system uses a digital computer which has a data bank that stores fixed parameters of the operation, such as the nature of the soil, the crop requirements for fertilizer and moisture, meteorological data, and other information useful in the control of irrigation and fertilizing. Such apparatus does not work in most soils since the reactive part of the impedance is too small at low frequencies and varies greatly from one soil to another. Moreover, it provides no efficient means for communicating the data to a central computer.

The task of manually determining the watering schedule of every individual station does not depend only on the station's specific soil requirements. One must also consider other variables like the available hydraulic pressure, supply voltage, the speed of wind, the presence of

individuals, etc... Only taking the hydraulic pressure into account is a fairly complex mathematical problems although it is most important. If the pressure is lower than the sprinklers nominal pressure, then the latter will not operate properly and some areas will not be irrigated. On the other hand, if the pressure is too high, energy will be lost, the irrigation process will take more time to complete and the irrigation of some stations may stretch beyond the permitted time window. Obviously most users do not have such expertise to compute the available pressure at any time. Therefore, the user will most often operate at higher pressures than required, waste energy and stretch uselessly the irrigation process.

On a golf course, the temperature of the greens must be kept below a maximum value depending on the grass type. This is achieved by wetting them periodically - the evaporation of water automatically cools them down. This process is called "*syringe*" and preferably is performed when no golfers are playing. Therefore, the irrigation of greens during the day is initiated manually when the grass temperature gets too hot and no players are around. In most sophisticated golf courses, the irrigation is remotely controlled via radio frequencies. However, one has to remember the number of every station (often up to 800 numbers) and enter them on the telephone keyboard of its talkie-walkie.

<u>OBJECTS AND STATEMENT OF THE INVENTION</u>

It is an object of the present invention to provide an irrigation system which overcomes the above described problems of presently known irrigation controllers and benefits from the above described scientific progress in soil water content measurement. This is achieved by providing a system which essentially comprises one irrigation controller per station, at

least one computer interface, an application software and at least one micro-computer to run the software.

Therefore, the present invention pertains to an irrigation system for controlling a plurality of watering station whereby these stations are irrigated in accordance with the specific soil needs of these stations, each station having valve actuating means; the system comprises:

a) computer means including a stored software program for establishing irrigation schedules for the watering stations;

b) a plurality of irrigation controllers, one at each watering station; each controller including a power line transceiver, a micro-processor, erasable non-volatile memory means, and an actuating circuitry for activating the valve actuating means in response to data received from the computer means;

c) a power line network for powering the controllers and serving as a medium through which the controllers communicate between one another and the computer means; and

d) a computer interface for interfacing the power line network with the computer means.

The present system is based on LonWorks^{tm} technology, developed by Echelon Corporation. All hardware modules power themselves directly from the power line. They also use the power line as a medium to communicate between each others. For this purpose, they use a LPT-20 (or later version) power line transceiver and the LonTalk^{tm} protocol developed by Echelon Corporation. Each hardware module has a Neuron^{tm} micro-processor which not only implements the LonTalk communication protocol but also the application software, or irrigation program, written in Neuron C^{tm}.

The power line network can be hybrid, that is comprising a number of high voltage sub-networks and several low voltage sub-networks. The high voltage network can travel longer distances but the low voltage is safer and does not require specialized personnel for maintenance. The low voltage sub-networks power themselves from voltage transformers connected to the high voltage sub-network. The voltage transformers typically offer various output voltages (taps) in order to adapt manually to voltage drop over long cable haul. These voltage transformers also comprise passive circuitry, comprising typically a communication transformer, to ensure that data flow freely in the whole network. Such communication transformers are also required to connect several distinct high voltage sub-networks.

As an option, the voltage transformer comprises active circuitry made of two power line transceivers connected back-to-back and acting as a data repeater. As a further option, two Neuron can be added which transform the unit in an intelligent repeater. Such a repeater can implement LonWorks' repeater firmware which not only boost the communication signal as the above repeater but also intelligently discriminate data which frees up some communication bandwidth on the network. By monitoring the output voltage and current, the Neurons also compensate voltage drop and prevent overcharge by modulating the output voltage even shutting it off.

The irrigation controller is a rugged and weatherproof device that can measure the amount of water and fertilizer in the soil and its temperature via a probe and energize the valve actuator of its irrigation station. The water content is determined through high frequency permittivity measurement using a metallic probe since it is the only rugged and precise mechanism existing today. Other sensing apparatus s may be used such as those described in applicant's copending application filed concurrently

herewith. Soil salinity is then determined from soil water content and conductivity. The irrigation controller also measures its own supply voltage. Finally, it has an optional analog input for measuring other local variables like hydraulic pressure, wind velocity, etc... The irrigation controller comes in two flavors: low voltage (15-48 VAC) and high voltage (85 - 250 VAC).

The computer interface module plugs directly into a personal computer and allows communication with any node of the network (or hardware modules). The serial version of the computer interface module connects to a modem, and allows communication with a remote computer via a telephone line or radio frequencies.

The application software runs on a personal computer, such as IBM PC compatible or Macintosh, connected to the network. It displays graphically an aerial photograph or a map of the irrigated land with the soil temperature, water content and the fertilizer level of each individual watering station. It also allows the user to manually open or shut any valve actuator at distance without leaving its desk. The user can also program the starting time and day and watering duration of every station.

The application software can also automate irrigation schedule of each station based on its specific water content, fertilizer content and temperature data and also on available hydraulic pressure, supply voltage, wind velocity, and human presence. It can also take into account some meteorological forecasts obtained by modem or entered at the keyboard.

Two modes are available to optimize the hydraulic pressure. In the first one, the application software will simulate the entire hydraulic network using known numerical algorithms based on the diameter, length, and roughness of very pipe, the altitude, nominal flow and pressure of very

sprinkler and the pressure/flow curve of the pumping station. Based on that theoretical simulation, individual station schedules will be computed and downloaded in every remote irrigation controller.

In the second mode, a number of pressure transducers scattered in the irrigated field connected to the analog input of some irrigation controllers allow real-time optimization of individual irrigation schedules. These irrigation controllers transmit in real-time the pressure data to their blind neighbors. Then, a station is irrigated only during permitted time windows whenever water is required and both sufficient pressure and voltage are available. Using this mode, the user can not know in advance in which order the stations will be irrigated but he can assign overriding priority levels to the stations.

Two modes are also available to automate syringing. In the first one, a remote sensor is connected to the analog input (which then acts as a digital input) of one of the irrigation controller of a green. This remote sensor informs this irrigation controller and its neighbors if any golfers are currently playing on the green. Syringe can be delayed accordingly.

In the second mode, a talkie-walkie is connected to a sound board plugged into the central computer. An off-the-shelf voice synthesis and speaker independent voice recognition software library or program provides a natural language interface to the application software. All commands related to soil monitoring and manual irrigation can be invoked at distance via talkie-walkie. The user comes to a green, checks its temperature and orders its syringe at will. No need to remember station numbers anymore. A typical conversation goes like this:

USER: Smart Rain ?

COMPUTER: Yes, Master ?

USER: Select green no 15.

COMPUTER: Green no 15 selected.

USER: Get temperature.

COMPUTER: The temperature is 32 degrees Celsius.

USER: Water 2 minutes.

COMPUTER: Watering for 2 minutes.

USER: Good Bye

COMPUTER: Good Bye Master.

An optional pumping station controller can be connected to the same network that powers the irrigation controllers. Its purpose is to maximize the hydraulic network life expectancy and energy savings. It will modulate the output pressure of the pumping station based on required pressure in the field. This modulation can be achieved by varying motors speed or varying the number of motors working. By minimizing pressure drop between the pumping station and the irrigating sprinklers, hydraulic and consequently electric energy is saved. Also, water hammers are minimized thus life expectancy of pipes extended.

The speed of motors is varied by modulating their frequency of operation. The pumping station controller generates such a variable frequency but constant voltage (typically 600 VAC) that powers very reliable synchronous 3-phases motors. The input of the controller can either be 2-phases low voltage or 3-phases high voltage supply. In rural areas where 3-phases power supply is not available, this option saves the cost of having the utility installing a dedicated 3-phases power line which is almost always very onerous.

Therefore, by individually optimizing the irrigation schedules of each watering station with respect to the specific needs of its soil and its

engineering constraints, the present system saves water, fertilizer, energy and manpower. The system of the present invention also improves the quality of the turf or crop because manual irrigation can never reach the level of precision of a dedicated computer. Moreover, the present system will promptly report any system defect. Therefore, the defect may be repaired before the turf or crop is harmed.

In a new installation, the system of the present invention reduces costs since cabling requirements are greatly reduced and controller housings are not required. Engineering costs are also lower since the network topology is rather straight forward. Since the cabling is simpler, maintenance and troubleshooting are greatly reduced. Moreover, the present system automatically reports the position of a short circuit or open circuit in the network. The absence of controller housings also reduces the chances of lightning strike and vandalism. Finally, the failure of an irrigation controller will put only one watering station out of order.

In existing installations, one advantage of the present invention is that the existing cabling network is used for communication thus eliminating the high costs of recabling or installing RF controllers. If the existing low voltage cable can withstand higher voltage, it is connected directly to the power main. Otherwise, a transformer can be utilized to lower the voltage on the low voltage side of the network. Such an hybrid network does not harm the communication as long as the power transformers have the appropriate communication transformer. As existing cabling grows older, risks of failure are prevented by the system which detects any fault and its position in the network.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given

hereinafter. It should be understood, however, that this detailed description, while indicating preferred embodiments of the invention, is given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the topology of a typical network using the system of the present invention;

Figure 2 is a block diagram of an irrigation controller; and

Figure 3 illustrates a block diagram of a sensor unit used in the present system.

DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 illustrates the topology of a typical network using the system of the present invention. A free-topology power line network is displayed consisting of a plurality of watering stations each including an irrigation controller 10, the controller being powered from several low voltage (15-48VAC) alternating power lines 11. These power lines come from field transformers 13 which not only reduce the voltage from the high voltage power line 12 but also allow the communication signal to get through. To the high voltage power line 12 is connected one or more computer interfaces 14, 15, 16 which are respectively connected to computers 18, 20 and 22, either directly as in the case of the main computer 18 or through telephone modems 24 and 26 in the case of the remote computer 20 or the radio frequency modems 28 and 30 in the case of the portable computer 22. Also connected to the power line 12 is a pumping station controller 31. This one could be connected to the low voltage side 11 as well.

One may interact with the application software in the main computer 18 in plain natural language using any walkie-talkie C in the field which communicates with another walkie-talkie or fixed radio station B through radio frequencies. The microphone input and speaker output of the latter walkie-talkie B are connected to the corresponding input and output of a sound board A plugged into a micro-computer 18. A speech interface

software in the computer 18 allows communication with the application software.

Each irrigation controller 10 is housed in a water proof casing and can be buried in the ground. This irrigation controller must operate in a wide range of temperature, typically from -40°C to +50°C. The irrigation controller is protected against indirect lightning and includes a probe for sensing water content, fertilizer content and temperature of the soil. Referring to figure 2, it is provided with two wires (line 32 and neutral 34) for connection to the low voltage power line and a third wire 36 for connection to a valve (not shown) which will actuate the irrigation of the station (the valve shares the same neutral 34). When connected to a high voltage line an isolated pair of wires is required to energize the valve (not shown). A fourth wire 38 provides an optional 4-20 ma current input for monitoring external devices such as pressure transducer, remote sensor, anemometer...

Each irrigation controller 10 further comprises a power line protection unit 40 protecting the irrigation controller against voltage surges (differential and common mode) mainly due to lightening which are frequent in open field, especially in certain areas. This protection may be achieved by using metal-oxide varistors and tranzorbs. The power line protection must protect the network against a failure of the irrigation controller by limiting current sunk using a PTC, for example, at the input. The protection unit decouples the power supply using a choke in order to increase the input impedance of the irrigation controller at communicating frequencies in order to improve the signal strength. It also filters electromagnetic interference caused by the switching power supply for preventing interference with communication signals and for complying with electromagnetic interference emission regulations.

The power line transceiver 42 allows the irrigation controller to communicate, e.i. to transmit and to receive, with other irrigation controllers and computer interfaces. The transceiver modulates the power line at high frequency for communication, for example 132.5 kHz. It tolerates strong signal attenuation typically 70dB, and uses approved equipment and protocol, typically Echelon Corp. PLT-20 transceiver and LonTalk protocol compliant with CENELEC EN50065-1. The transceiver works in a free-topology network which allows retrofitting easily existing hybrid low-high voltage cable networks and saving on cabling in new installations.

Each irrigation controller also includes a switching power supply 44, a central processing unit 46 and a sensing unit 48.

The switching power supply 44 generates power for the transceiver 42, typically 5, 12 and 24 volts. It generates power for the central processing unit 46 and the sensing unit 48. The power supply is switching for reducing size and heat loss; its switching frequency is chosen to prevent harmonics interference with communication frequency;. The power supply may accept wide input voltage range, typically 85 to 250 volts (high voltage) or 15 to 48 volts (low voltage), AC or DC, 50 or 60 Hz. This range is compatible with both European and American power lines and low voltage networks; it tolerates important voltage drops to thereby allow smaller power cabling and related savings.

Each irrigation controller further includes a valve driver 50 which detects open and short circuit conditions. When the irrigation controller is operating at low voltage, an opto-isolated TRIAC in the valve driver will modulate the valve output in order to limit the valve current. When the irrigation controller is operating at high voltage, an inv rter in the valve driver 50 regenerates a square wav of 24 volts (AC or DC) to energize the

valve. Also the power supply's primary and secondaries are isolated for security and to prevent current loops through the ground.

Using a stainless steel probe 54 buried in the soil, the sensing unit 48 measures the permittivity and conductivity of the soil for determining water and fertilizer content. The sensing unit also measures the temperature of the soil using a thermistor located at the tip of the soil probe.

Each irrigation controller 10 comprises also a valve end protection unit 52 which will protect the irrigation controller against too high current or short circuit using PCTs. It will also protect the irrigation controller against inadvertently plugging the valve output to the power line or any other wrong connection. Finally, this unit also protects the irrigation controller against voltage surges.

The central processing unit 46 contains a micro-controller that handles communication protocol and inputs/outputs using a "Neuron" chip made by Echelon Corporation. It contains PROM and/or EPROM (typically flash EPROM) for storing firmware, irrigation schedules, historical data and user's setpoints. It has a unique fixed communication address. The firmware can be partially or totally downloaded remotely for upgrading purposes, if flash EPROM option is present. This unit may include a real time clock with battery back-up for keeping time and day and broadcast them on the network; otherwise, it updates its time and day from the network. It will shut off the valve if the current gets too high or temperature too low. The irrigation controller may act as an intelligent repeater for allowing the computer to communicate with another irrigation controller which it can not communicate directly with, because of signal attenuation and/or reflection. The processing unit 46 will process permittivity and conductivity of the soil to determine water and fertilizer content. It will also process the

thermistance resistance to determine the temperature of the soil. Finally, it will operate the valve based on a programmed and downloaded irrigation schedule and/or based on water content, fertilizer content and/or temperature of the soil.

The computer interfaces 14, 15 and 16 interface the serial ports of the computers with the power line network or plug directly into the computer bus; they allow the user to control the network from a computer. It contains the same transceiver and micro-processor than the irrigation controller and it implements the same communication protocol.

Each computer 18, 20 or 22 and its software allow the full and centralized control of the irrigation system via a user friendly graphical interface. It contains a low level driver for implementing the communication protocol, typically LonTalk, and for communicating with an irrigation controller on the power line network. The computer displays a colour map of the irrigated field, the sprinklers and pipes and show graphically the different levels of water content, fertilizer content or temperature of the soil. It will allow to manually open or shut any valve in the field and it will allow to program any number of irrigation schedules. The computer can automatically irrigate the field based on temperature data, water and fertilizer content data and user's set points without the need for human intervention; it optimizes irrigation schedules based on the flow capacity of each watering station, pipe and pumping station. The computer may use a modem to get meteorological forecast data to optimize the irrigation process. The computer detects instantly and locates any damaged cable in the field whether it is a power line cable or a valve cable. It will also interface with the pumping station controller 31 if one is used.

If used, the pumping station controller 31 has a set of input and output ports, some digital and some analogue (4-20 ma or 0-10VDC) for controlling partially or totally a pumping station (not shown). The controller 31 will communicate over the power line network via the same transceiver and protocol and it will allow the irrigation software to control the pumping station and monitor its status. The controller will also allow automatic fertigation by energizing one or more injection pumps which will inject liquid fertilizer into the irrigation water. This controller normally will reside in the pumping station building.

The advantage of fertigation over traditional fertilization is tremendous. First the manpower is saved. Second, small amounts of liquid fertilizer can be added every day instead of bigger amounts periodically. Therefore, cheaper chemical fertilizers can be used instead of slow-release organic ones and the "concentration versus time" curve will still be flatter which is better for the plant and reduces fertilizer usage and pollution accordingly.

Chemigation can be achieved in the same fashion. Liquid pesticide is added to the irrigation water instead of liquid fertilizer. This process and its advantages are similar to fertigation except that the irrigation controller provides no internal mean of determining the required level of pesticide neither its kind. However, several external devices can be connected to the analog input of the irrigation controller such as commercially available "bug counters".

Referring to figure 3, an improved sensing unit 48' is illustrated. It comprises a variable frequency oscillator 60 that generates a sinusoidal signal at a high frequency *f* specified by the micro-processor of the central processing unit 46, typically from 50 to 225 MH_z. An RF amplifier 62 may

amplify this signal generated by the oscillator and feed it to a U-shaped probe 64 via a resistor R_o. The probe is a tube made of stainless steel that acts as a transmission line. It is buried in the soil where permittively and conductivity are measured. A thermistor (not shown) is inserted at the end of the probe 64 in order to measure the temperature of the soil. A mixer 66 multiplies the voltage V_2 across the probe by cosinus f, where f is the angle between V_2 and the current I flowing through the probe. The analogue to digital converter 68 converts V_2 cos f in digital format readable by the micro-processor.

The velocity of waves propagating through the probe depends on the permittivity e of the soil in which it is buried and slightly on its conductivity G. A sinusoidal signal generated by the VFO will travel through the probe in the forward direction at a specific velocity, will be inverted and reflected at its end, and then will travel back in the reverse direction at the same speed, creating standing waves. The plot of V_2 against *f* would roughly look as a sinus. When the length of the probe is an odd multiple of one fourth of the wave length of the signal, the resistance of probe R_p and V_2 are maximum; when it is an even multiple, R_p and V_2 are minimum. On the other hand, the more conductive the soil is, the more attenuated the reflected wave and standing waves will be. Therefore, the conductivity G can be computed by the microprocessor as a function of the minimum and maximum values of R_p. The permittivity can be computed as a function of both G and the frequencies *f* at which these minima and maxima occur.

Although the invention has been described above in relation to one specific mode, it will be evident to a person skilled in the art that it may be modified and refined in various ways. It is therefore wished to have it understood that the present invention should not be limited in scope, except by the terms of the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. An irrigation system for controlling a plurality of watering stations whereby said stations are irrigated in accordance with the specific soil needs at said stations, each station having valve actuating means, said system comprising:

a) computer means including a stored software program for establishing irrigation schedules for said watering stations;

b) a plurality of irrigation controllers, one at each watering station; each said controller including a power line transceiver, a micro-processor, erasable non-volatile memory means, and an actuating circuitry for activating said valve actuating means in response to data received from said computer means;

c) a power line network for powering said controllers and acting as a medium through which said controllers communicate between one another and said computer means; and

d) a computer interface for interfacing said power line network with said computer means.

2. An irrigation system as defined in claim 1, wherein said micro-processor of said irrigation controller has a stored program allowing said controller to act as an intelligent repeater to allow said computer means to communicate with another irrigation controller with which it cannot communicate directly.

3. An irrigation system as defined in claim 1, wherein each said irrigation controller further comprises an internal switching power supply

for feeding low voltage direct current to said micro-processor, said memory means, said transceiver and said actuating circuitry.

4. An irrigation system as defined in claim 3, said micro-processor allowing said actuating circuitry to operate in ac mode or dc mode; said actuating circuitry including an inverter for converting said low voltage direct current into an alternating current for powering said valve actuating means of said watering station when operating in ac mode; said actuating circuitry output being a pair of wires isolated from the high voltage power line.

5. An irrigation system as defined in claim 3, wherein each said irrigation controller is connected to a variable low voltage line, said irrigation controller measuring variable line voltage; said actuating circuitry having an output voltage and including a TRIAC modulating said output voltage while energizing said valve actuating means of said watering station; said micro-processor allowing said actuating circuitry to modulate said output voltage based on said line voltage in order to limit the current sunk by said valve actuating means of said watering station; said actuating circuitry output being a single wire, the neutral being common with the low voltage line.

6. An irrigation system as defined in claim 1, wherein said irrigation system operates on LonWorks technology and communicates using LonTalk protocol; said micro-processor being a Neuron processor.

7. An irrigation system as defined in claim 1, wherein each said irrigation controller includes means for collecting soil data at ach watering station for measuring the needs for watering at said station; said

soil data including water content; said computer means including display means for displaying data collected by said collecting means.

8. An irrigation system as defined in claim 1, wherein each said irrigation controller includes means for collecting soil data at each watering station for measuring the needs for watering and for fertilizing at said station; said soil data including water content and fertilizer content; said computer means including display means for displaying data collected by said collecting means.

9. An irrigation system as defined in claim 8, wherein said measuring means measure at high frequencies the permittivity and conductivity of the soil at said watering station.

10. An irrigation system as defined in claim 8, wherein said soil data further includes soil temperature and wherein each said irrigation controller includes means measuring the temperature of soil at said watering station; said display means displaying the temperature measured for each watering station.

11. An irrigation system as defined in claim 8, wherein said soil irrigation controller has a universal input wire for monitoring external measuring device.

12. An irrigation system as defined in claim 11, further comprising a pumping station controller connected to said power line network and communicating with said irrigation controllers and said computer means through said network; said pumping station controller including means for

adding one or more liquid fertilizers to irrigation water at said watering stations.

13. An irrigation system as defined in claim 12, said pumping station controller regenerating a three-phase electrical power for pumping station motors and modulating the pumping speed of said pumping station by varying the frequency of said power ; and a potentially variable voltage source and/or different number of phases powering said controller.

14. An irrigation system as defined in claim 11, said stored program being adapted to automate irrigation, fertigation and chemigation schedules of each watering station based on soil requirements on predefined engineering constraints and on user-defined constraints to minimize energy, water, fertilizer usage and manpower.

15. An irrigation system as defined in claim 1, further including means allowing a user to interact with said system via natural speech command and a walkie-talkie in the field.

16. An irrigation system as defined in claim 1, wherein each said irrigation controller further comprises a power line protection unit connected to said power line network and a valve end protection unit connected to said actuating circuitry.

17. An irrigation system as defined in claim 1, wherein said computer interface communicates with said computer means via a modem.

18. An irrigation system as defined in claim 1, wherein said power line network further comprises high voltage power line network means

and low voltage power line network means; said low voltage power line network means being powered from voltage transformers connected to said high voltage power line network means; said voltage transformers including passive circuitry to allow communication signal to travel from said high voltage power line network means to their respective low voltage power line network means and vice-versa; said voltage transformers including different voltage outputs on secondary side thereof to allow manual adjustment for voltage drop on long cabling.

19. An irrigation system as described in claim 18, wherein said voltage transformers further comprise means for measuring the voltage and the current on the secondary side of said voltage transformer; means for disconnecting the voltage output of said voltage transformer of said current is above a maximum limit and if said voltage transformer is not adequately connected.

20. An irrigation system as defined in claim 18, wherein said voltage transformer further comprises: at least one Neuron and at least one power line transceiver; means for varying voltage output of said voltage transformer; software means for controlling said means for varying said voltage output based on output voltage or current or remote command or variable line voltage powering an irrigation controller powered by said voltage transformer.

21. An irrigation system as defined in claim 8, wherein said measuring means consist of:

a) a probe adapted to be buried in the soil to be measured and consisting of two parallel metallic rods;

b) oscillator means for feeding a high frequency sinusoidal signal to said probe;

c) means for measuring the electrical resistance across said rods at any frequency generated by said oscillator means;

d) circuit means allowing said micro-processor to vary said frequency and to read said resistance; and

e) software means for computing permittivity as a function of the frequency at which said resistance is maximum or minimum and computing said conductivity as a function of the minima and maxima values of said resistance.

22. An irrigation system as defined in claim 20, wherein said means for measuring the electrical resistance across said rods consist of a resistance component connected between said oscillator means and said probe, a mixer multiplying the voltage across said rods with the voltage across said resistance component, and a low-pass filter filtering out the high frequency component of the multiplication.

23. An irrigation system as defined in claim 21, further comprising means for measuring the output voltage of said oscillator means, means measuring said voltage across said rods, circuit means allowing said micro-processor to read said voltages; and software means for computing said conductivity as a function of the minima and maxima values of said resistance across said rods and said voltages.

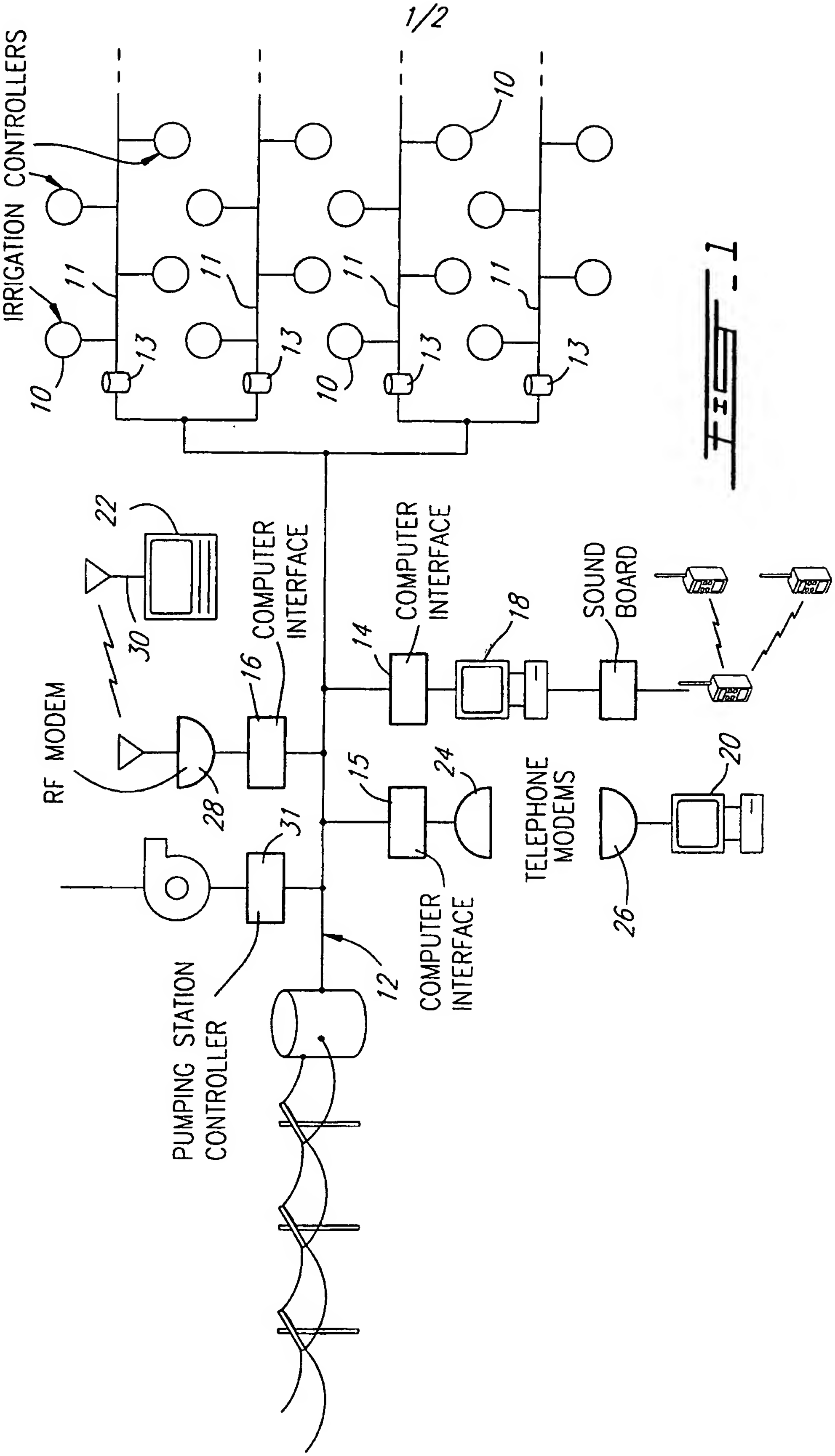
IRRIGATION CONTROLLERS
10
11
13
12
14
15
16
18
20
22
24
26
28
30
31
RF MODEM
COMPUTER INTERFACE
COMPUTER INTERFACE
COMPUTER INTERFACE
SOUND BOARD
TELEPHONE MODEMS
PUMPING STATION CONTROLLER

FIG. 1

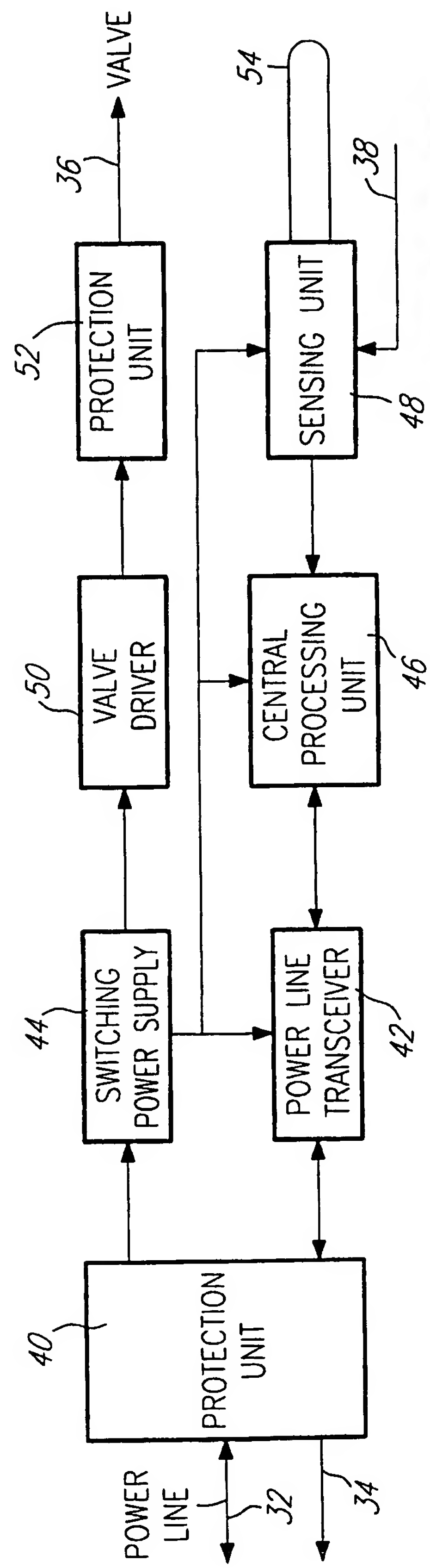
POWER LINE
32
34
40
PROTECTION UNIT
44
SWITCHING POWER SUPPLY
42
POWER LINE TRANSCEIVER
50
VALVE DRIVER
46
CENTRAL PROCESSING UNIT
52
PROTECTION UNIT
48
SENSING UNIT
36
VALVE
54
38

FIG. 2

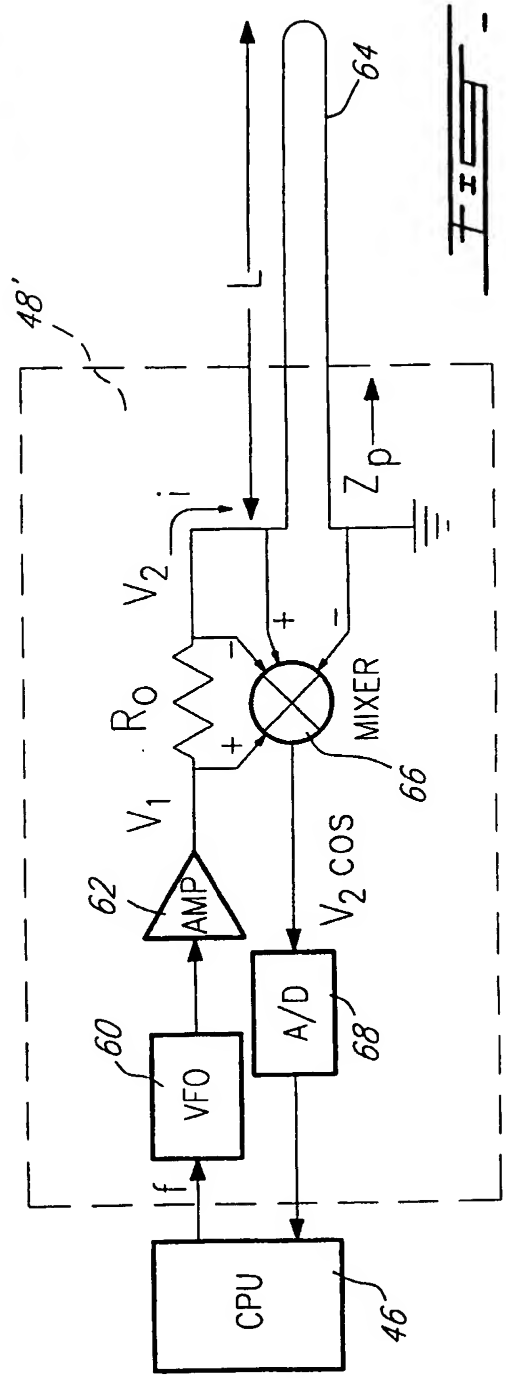
48'
CPU
46
f
60
VFO
62
AMP
68
A/D
V_1
R_O
V_2
i
MIXER
66
V_2 COS
L
Z_p
64

FIG. 3

INTERNATIONAL SEARCH REPORT

Int. .onal Application No
PCT/CA 96/00598

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A01G25/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A01G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,4 626 984 (UNRUH ET AL.) 2 December 1986 see the whole document	1-4,7, 16,17
A		5,6,8, 10,11, 15,18
X	FR,A,2 680 629 (SETA) 5 March 1993 see page 2, line 28 - page 5, line 33	1,7,17
A		10
X	WO,A,95 22799 (WATERLINK SYSTEMS) 24 August 1995 see page 9, line 6 - page 10, line 24	1,7,17

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
19 December 1996	17. 01. 97

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 96/00598

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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X	FR,A,2 665 051 (SADIMATO) 31 January 1992 see the whole document	1,7
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